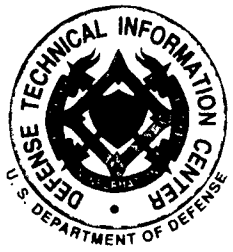

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A SYSTEM OF METHODS FOR IDENTIFYING THE CAUSES OF FAILURES AND ACCIDENTS OF AERONAUTICAL ENGINEERING

Yu.Korovkin,
Doctor, Scientific & Technical Centre "EXPERT"
RUSSIA, 140003, Moscow region, Liubertsy-3, a/b 8

Abstract: The scientific and methodological foundation as well as the substance are presented of the system of methods for identifying the causes of failures and damages of aviation materiel developed on the basis of theoretical and experimental investigations and generalization of multiyear experience in practical work in this field.

Key words: Accident; aviation; methods; failure; cause; engineering.

The identification of the true causes of hazardous failures and accidents of technical equipment is the necessary condition for developing and accomplishing effective measures aimed at precluding their recurrence.

The identification of these causes is a highly complex task especially when the accidents are accompanied by the secondary destruction of equipment units taking place as a result of explosion, fire, collision of damaged parts, etc.

Aviation belongs to the area of mankind's activity where the solution of such a problem is of particular urgency. ICAO's documents (Supplement 13) only establish a general order of organizing the investigations of aviation accidents (AA) and serious incidents.

Created by Russian scientists is the system of mathods for examina ng faulty pieces of aeronautical engineering (FPAE). Tnese examinations feature a series of principal peculiarities which differ them from other investigations of technical equipment.

The major peculiarities formulated on the basis of generalizing a multiyear experience in post-accident examinations of FPAE are as follows.

1. The picture of the origination and development of the phenomenon under investigation, which is as a rule resulted from a variety of causes, should be reproduced.
2. The sources of information used in failure cause identification (parts and units of FPAE, flight recorders, etc.) have considerable damages and destructions.
3. Functional connections between separate elements of aircraft (AC) systems are disrupted and some of these elements are often not found at the accident site (due to being completely destructed, burned, fallen into water, etc.).
4. The piece under examingation where the gailure occured

resulting in the accident is a single one.
5. The information used in failure cause identification esists in many cases in the form of microscopic tracks.
6. The AC's systems under examingation have often different principles of functioning (from mechanical to electronic).
7. The questions relating to defferent sciences (from mathematics to criminalistics) have often to be solved in the course of a post-accident investigation.
8. Significant part of the investigation is commonly carried out in field conditions, directly at the accident site.
9. The investigation has to be conducted in the shortest possible time.

The complexity, comprehensive, multiaspect and multidisciplinar character, elevated labour content, involvment of large number of various specialists, joint application of formalized, empirical and heuristic methods are responsible for the nees to use a system approach to these investigations and to create a system of methods ensuring the solution of entire complex of problems arising in all stages of investigating AA.

The system of methods created is based on the methodology developed of examinating RPAE (Fig. 1). In developing this methodology the experience in examinating thousands of AA was generalized, factors acting on pieces of aeronautical engineering (AE) during AA were revealed, laws of the phenomena occuring in accidents were determined, available data on variations in AE condition during operation and repair were used, structural and functional features of AE pieces were taken into account, methods of natural sciences were employed for examinating objects and phenomena.

Taken as an important element of the methodology is the clear statement of the problem on examinating FPAE on the basis of considering an AA model combined with defining possible kinds and sousces of information (Fig.2).

In developing scientific and methodological basis of examinating FPAE, the principles of conducting sich examinations were formulated. They include both known general principles of scientific investigation and specific principles accounting for the peculiarities of examining RPAE. The most important of them is the assurance for the credibility of results to be obtained. This is a major requirement imposed on the methods which, in particular, is satisfied with the following ways:

using a variety of indications and methods based on different physical principles in solving the problem;

maximum possible recovery of the information distorted as a result of acting AA factors;

carefully checking the information used for its validity by means of excluding its inherent contradictions;

documenting all the results obtained during an investigation;

strictly determining the sequence of operations which excludes the errors capable of resulting in loss of failure information;

combining analysis and synthesis of phenomena under

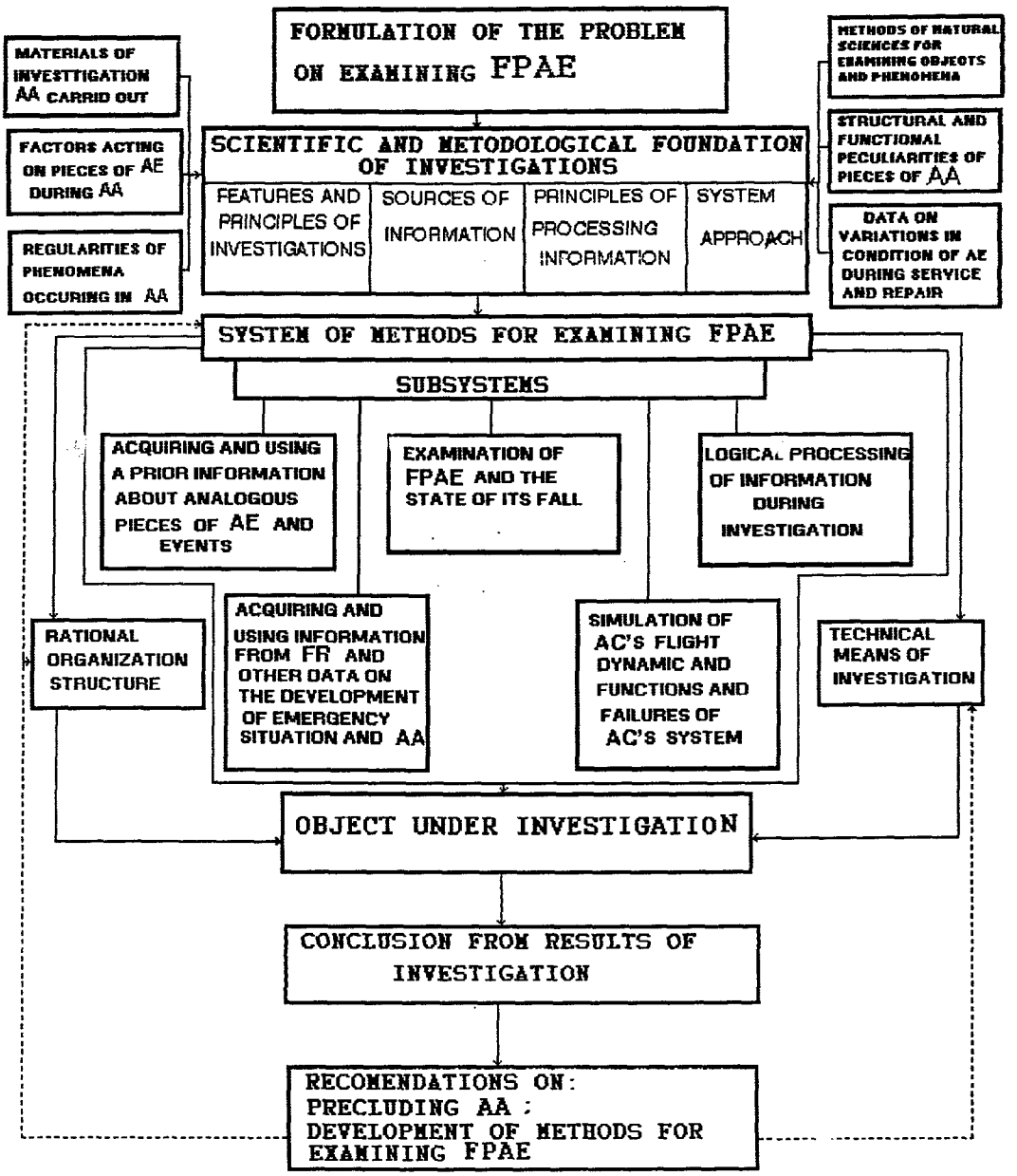

Fig. 1 Methodology of examining faulty pieces of aeronautical engineering (FPAE).

Note: *AA - aviation accident; AE - aeronautical engineering; FR - flight recorder; FPAE - faulty piece of aeronautical engineering.*

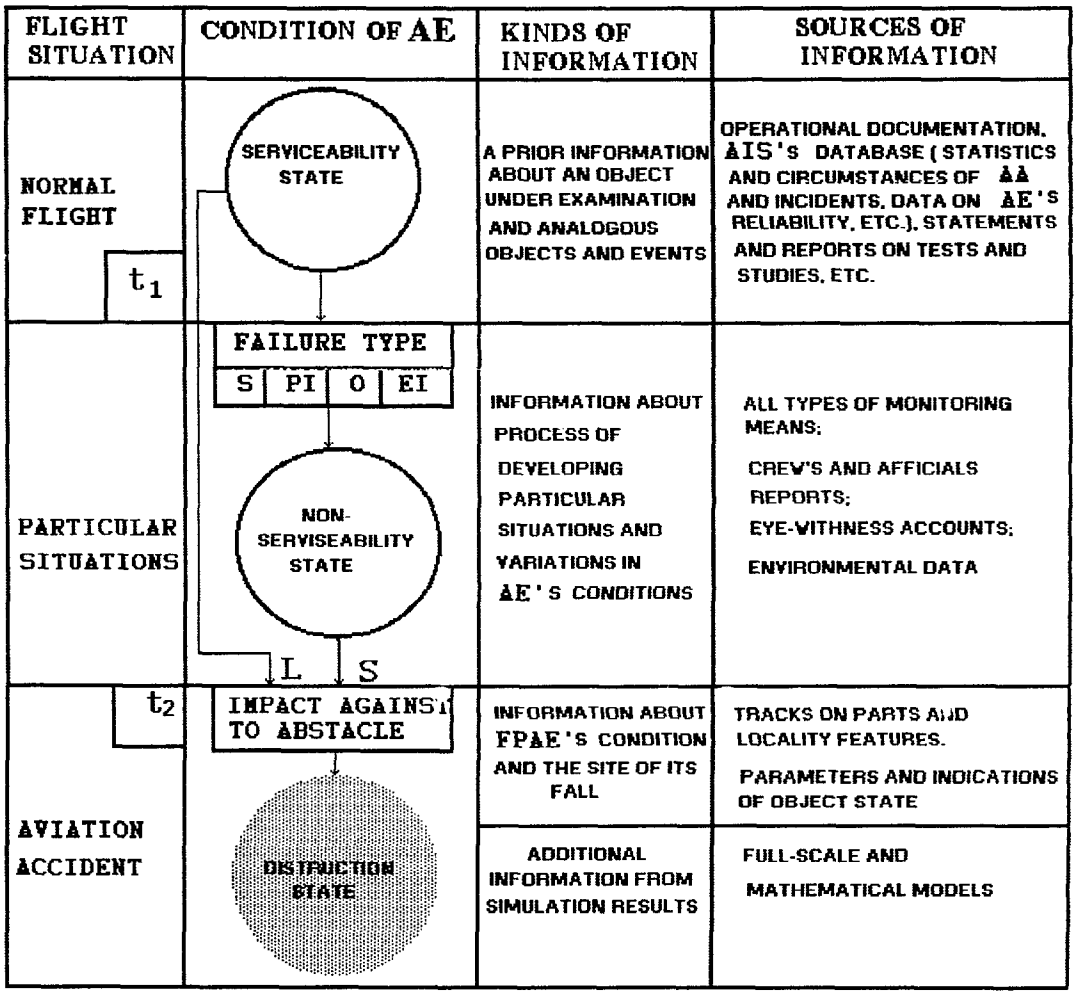

Fig. 2 Formulation of the problem on examining FPAE

Known: *1. At the instant* t_1 *the piece of AE was in serviceable state (SS).*
2. At the instant t_2 *the piece of AE was in destruction state (DS) as a result of impact against an obstacle.*

To be determined: *1. Way of transition (S or L) from SS to DS (that is, whether the failure was in flight).*
2. What is the failure cause:
a) device failed (unit, block, assembly, element);
b) failure cause (structural (S), production-induced; (PI), operational (O), externally-induced (EI))?

examination.

The system of methods for examining FPAE constitutes the major content of the methodology. According to the types of information used in examinating FPAE (see Fig. 2) and the peculiarities of its acquisition, application and processing, the system of methods of investigations includes the subsystems depicted in Fig. 1. Consider each of them.

1. The first one is based on the automated information system (AIS) "Safety" that include civil and military subsystems. The databese of this AIS contains the information about known AAs, incidents, results of investigations carried out.

In addition, widely used are the albums of illustrations of failures made up for basic types of AC and containing the copies of monitoring records, photos, schemes showing the circumstances under which the malfunctions arised and manifested themselves as well as the information reports issued for servicing organizations concerning AAs and incidents.

2. At present a main place in the subsystem of the mathods for obtaining and applying the information about developing the emargency situation and the AA is occupied by the methods ensuring the effective use of monitoring records, especially the data of flight recorders (FR). For the FR information to be used with the purpose of determining AC's flight parameters and assessing the serviceability of an AE and identifying failure causes, a series of user guides were worked out covering practically all basic types of airplanes and helicopters now in service in Russia. On modern AC equipped with magnetic recorders an automated input of flight information in a personal computer was assured and associated algorithms and programs were developed, which provide the maximally full use of recorded data for both evaluation of AE's serviceability and solution of flight -dynamics problems. By way of example, displayed can be the AC's flight trejectory and its spatial attitude. It should be noted that the PC-based system created for processing flight information with the aim of assessing the AC's condition and preventing failures is applied not only in Russia. Thus, for instance, successfully employes in Germany since April 1995 is the system APM OK with the aid of which the data on several thousands of flights of Luftwaffe's MiG-29 aircraft have already been processed.

But the effective use of flight information in investigating AA is often hampered by the fact that the protected airborne recorders in many cases do not assure the complete retention of recorded information. In this connection, developed and widely used are the methods for recovering and obtaining information from both optical and, especially, magnetic recorders. Corresponding user giudes give the recomendations for those people participating in investigation of AA, which provides the retention of recorded information at an accident site.

3. Flight recorders (even in cases of their undamaged state)

carry the information about variations of a limited number of flight perameters and AE's operation. Because of this for evaluating the serviceability of AC's systems, locating a failure and identifying its cause, there is a need to examine the condition of the FPAE and the site of its fall. With this purpose a complex of numerous methods and procedures based on different physical and chemical principles are used which constitute the third subsystem. Used as its basis is the regularity established of reflecting events and phenomena occuring in AE failures and AAs in various tangible tracks on parts and locality features. As a result of generalizing the materials of a rich variety of AAs and experimental studies, the regularities of the formation of tracks on FPAE were revealed based on which are the methods and procedures allowing one to find informative tracks on damaged AC's fragments and "make them tell".

For example, it was found that in the case of impact against an obstacle one can find the tracks reflecting the following characteristics of the AE condition:

kinetic energy of rotating structure members (of engines, generators, pumps, etc.);

pressure of working media (fluids, gases);

amount (volume) of working media and expendable fluids, gases in AC's systems;

position of actuator devices;

position of the elements of automatic systems;

position of the elements of instruments and indicators;

presence (or absence) of residual magnetizationof a definite level;

degree of parts' heating.

Also, structure parts carry the tracks of the conditions of their destruction, which enables making a distincion between damages, fires, explosions that can take place in flight and the same phenomena occuring in the case of impact against an obstacle.

For the information about the serviceability, mode and conditions of operation of a unit under examination to be obtained on the basis of analyzing the tracks, special procedures were developed giving the relationship between track features (colour of oxide film, arrangement of metallized coatings, relative positions of the elements of spool-and-sleeve pairs, etc.) and some parameters characterizing the condition of an object under examination. Such relationships were found on the basis of special studies (flight and groun-based tests, simulations). These relationships in the form of nomographs, plots, tables, sets of standard specimens are given in user guides for concrete AC.

4. In modern conditions simulations are widely used in investigating AA. Primarily it is the mathematical simulation of flight dynamics and AC's trajectories using the data from FR and other information about the AA and the condition of the FPAE.

Physical simulation (both pilot-in-the-loop and hardware-in

-the-loop) is employed in cases that the information from FR and data obtained on the FPAE condition are insufficient for identifying causes of failures in AE. This type of simulation is intended for establishing:

possibilities and durations of altering the revealed part's defect to the failure of the unit or subassembly;

the nomenclature of malfunctions leading to the failure registered in flight;

actual operational conditions of the part and boundary conditions under which the malfunction appears;

correspondence between part's damages and a definite unit state (serviceable or non-serviceable);

possibilities of practical realization of stated hypotheses regarding the causes of failures.

The totality of the mathematical and physical simulation methods constitutes the fourth subsystem of the methods for examining FPAE.

5. Finally, the fifth subsystem includes the methods ensuring logical processing both the primary information in all stages of investigating AA and the analysis of all data obtained in the course of the investigation for formulating a conclusion on the basis of its results. Among them we would like to set off the method for constructing the schemes of the connection betweem causes and effects which is used in every examination of FPAE and ensures a purposeful acquisition and processing of information. The construction of a cause-effect linkage scheme is accomplished on the stage-by-stage basis beginning with a final effect derived from the analysis of the circumstances of the AA and data from the monitoring system and ending with the prime cause. Currently available is a special software for PCs and methodological guides containing standardized schemes of cause-effect schemes that are to be refined and added with fresh data gained during a concrete investigation.

For attaining a required logical succession in acquiring and processing information, algorithms were developed relating both to separate stages on an investigation and to entire process of examining AE during the investigation of AA.

For conducting examinations of FPAE, developed on the basis of the above-presented methods and practically used is the system of technical means which includes both specialized tools and equipment usable in other areas of science and engineering. In military aviation special-purpose flying laboratories are brought into use for in-site investigations which are equipped with devices necessary for work in field conditions.

Conclusion : The system outlined of the methods for examining faulty pieces of aeronautical engineering provides a sufficiently comprehensive and plausible solution to the complex of the problems associated with determining the serviceability of aeronautical engineering and identifying the causes of its failures in all stages of investigating aviation accidents.